

Next generation of miniaturized high spectral resolution spectrometers

A journey from space exploration to medical diagnoses

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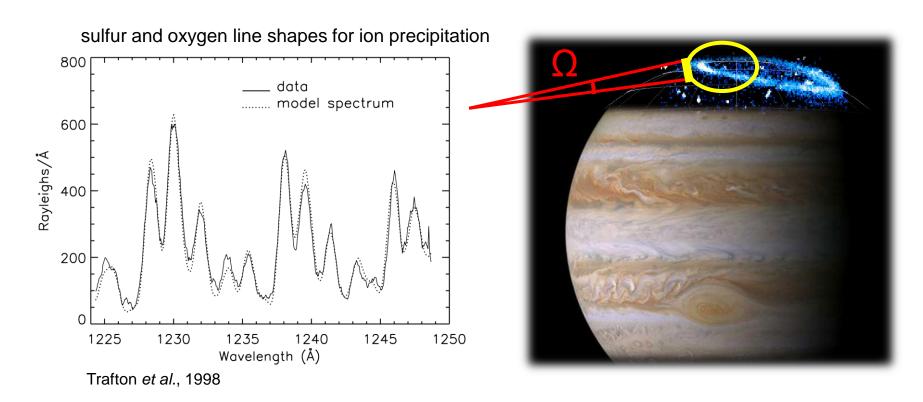
SHS will reveal incredible spectral detail in a cometary coma/tail





High Spectral Resolution Spectroscopy

High spectral resolution is needed for fine relative motions, multiple sources, isotope ratios, temperature, turbulence, currents, and etc.

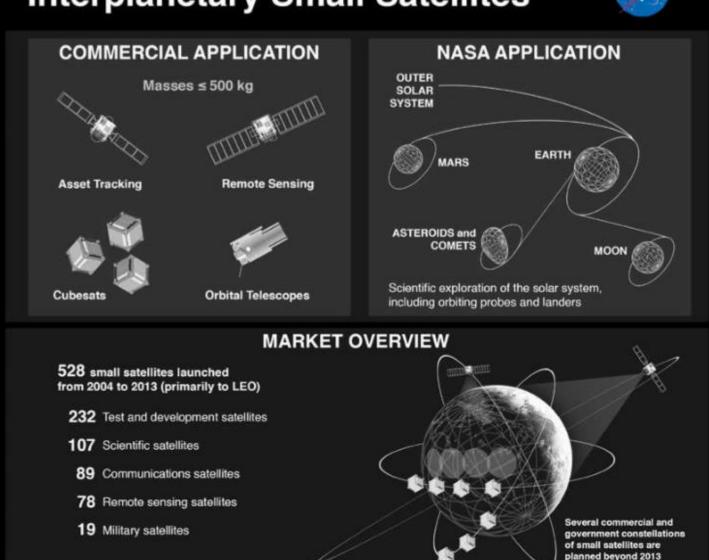


Jupiter's northern aurora, (~1 Å) from Hubble-STIS

Upper panel: image of the FUV Jovian northern aurora observed with WFPC2

Interplanetary Small Satellites





Public-Private Partnership for Space Capability Development, April 2014



High Spectral Resolution Spectrometry

Spatial Heterodyne Spectromter

No, 1D or 2D spatial information Compact/miniature Small aperture telescope Low data volume All-reflective design High tolerance (optomechanical, temperature)

Grating spectrometer

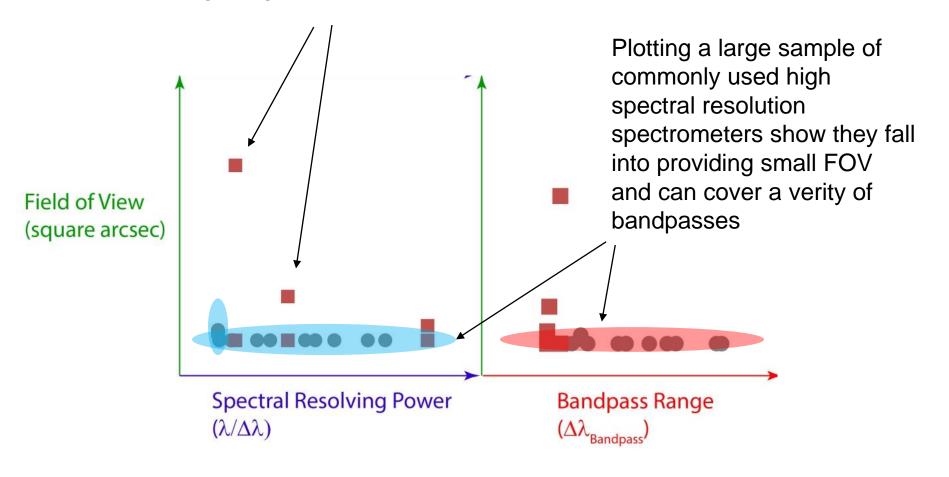
1D or 2D spatial information (data cube capability) Well known concept/heritage All-reflective design Point sources





SHS breaks out off the high spectral resolution spectrometers restrictions

SHS can access wide FOV with high R that is not possible with grating spectrometers





Raman Spectroscopy

Raman spectroscopy is a well known common method to measure biomarkers. Since vibrational spectroscopy is specific to the chemical bonds and symmetry of molecules, Raman spectroscopy is commonly used in chemistry and provides a fingerprint to identify molecules. In medicine and gas analyzers, Raman Spectroscopy is used for real-time monitoring of anesthetic and respiratory gas mixtures which is used during some surgeries. In solid state chemistry, Raman has a key role in the bio-pharmaceutical industry; it is used to identify (ID) active pharmaceutical ingredients (APIs) and identify the polymorphic form of the API, in case of multiple polymorphic forms.



Beneficiary factors

Reflective Spatial Heterodyne Spectrometers have many unique advantages over all previously-reported Raman spectrometers. For instance:

More compact size: enables miniaturized and compact form factor in small and compact platforms. For commercial use, this instrument replaces a system in the size of a refrigerator into a backpack size instrument that can be carried to remote locations.

Higher spectral resolution: enables the detection of fine and hard to detect spectral features to avoid ambiguity and increase sensitivity and accuracy.

Wider FOV: enables higher throughput without the need to larger instrument or larger microscope to detect faint spectra signatures.

Reflective design: enables the usage for a broad wavelength range from visible to shorter wavelengths into UV and extreme UV without the complication of refractive optics. SHS allows heterodyning around the laser wavelength to increase the resolution in the deep UV.

No moving parts: enables using a pulsed laser and gated detector in ambient light conditions so the entire Raman spectrum can be acquired with each laser pulse.



Interference Pattern

$$E_{1}(r,t) = E_{01}\cos(k_{1}.r - \omega t + \varepsilon_{1})$$

$$E_{2}(r,t) = E_{02}\cos(k_{2}.r - \omega t + \varepsilon_{2})$$

$$I = E_1^2 + E_2^2 + 2 < E_1 \cdot E_2 >$$

$$< E_1.E_2 >$$

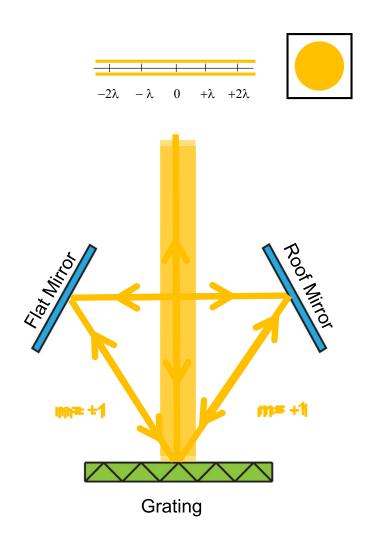
= $E_{01}.E_{02}\cos((k_1 - k_2).r + \varepsilon_1 - \varepsilon_2)$

Conventional Interferometry

SHS



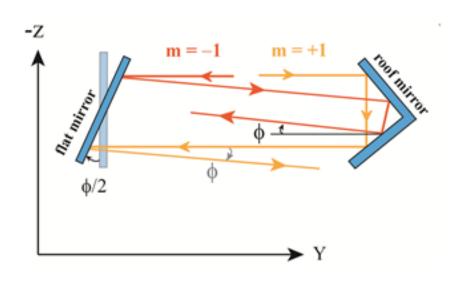
SHS is a cyclical interferometer

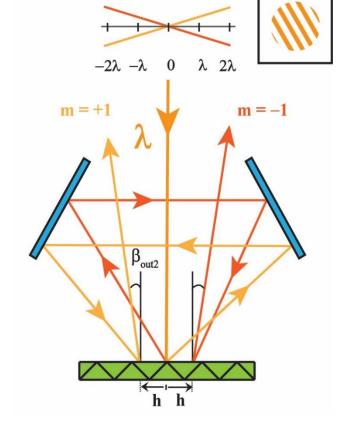




SHS is a cyclical interferometer

$$E_{01}.E_{02}\cos((k_1-k_2).r+\varepsilon_1-\varepsilon_2)\neq 0$$



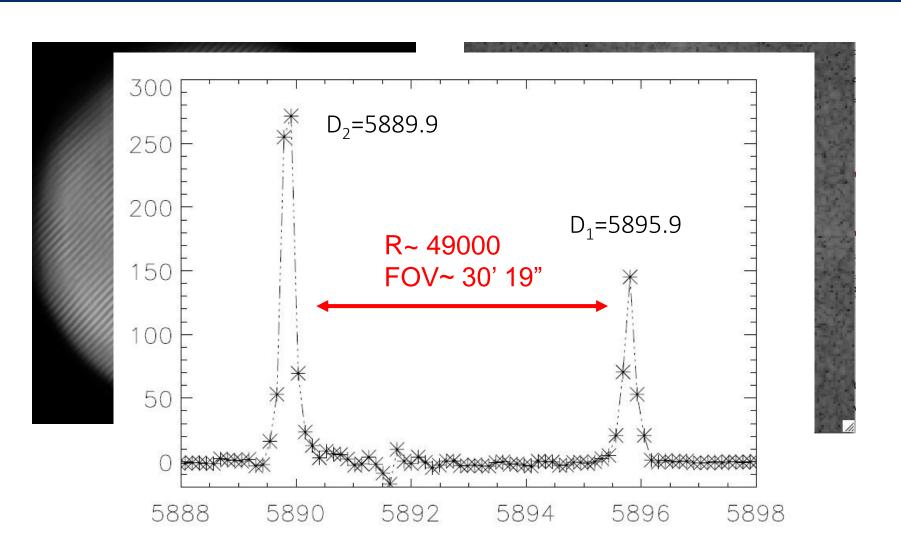


Top view

Side view



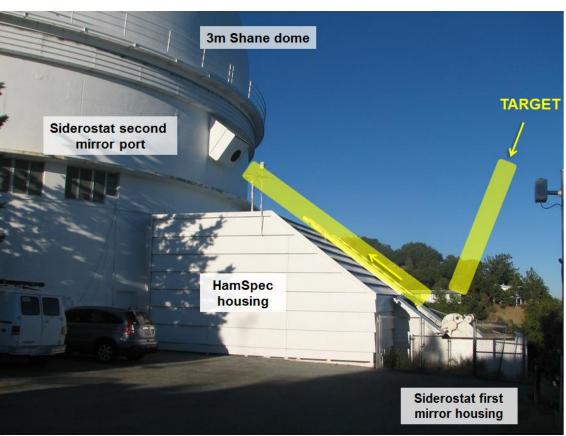
Na Lamp D lines

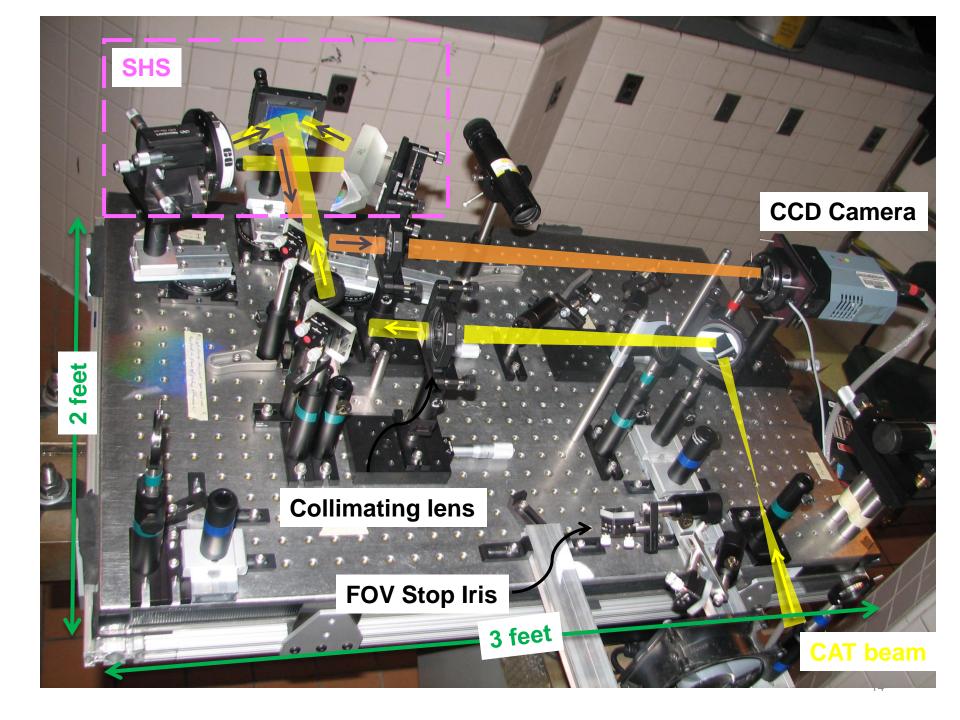




Khayyam: the first facility-class SHS constructed

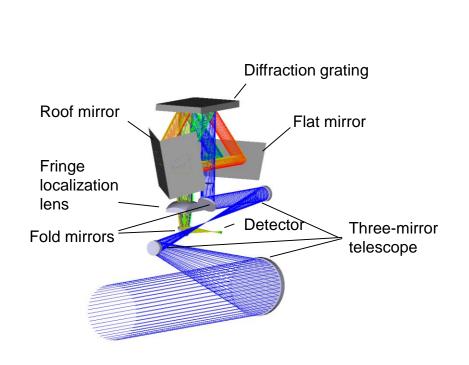


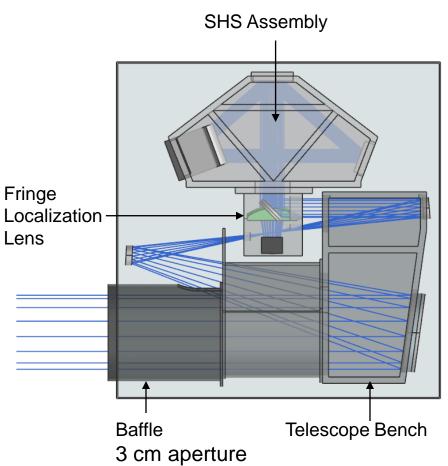






SHS for Small Platforms





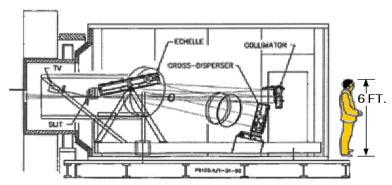


In comparison with similar spectral resolution instruments



STIS - Hubble (2.4 m)

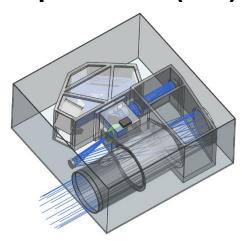
Keck spectrometer (HIRES) \$4 million, 8 tons, 5 m length



HIRES - Keck (10 m)



HamSpec - Lick (3 m)

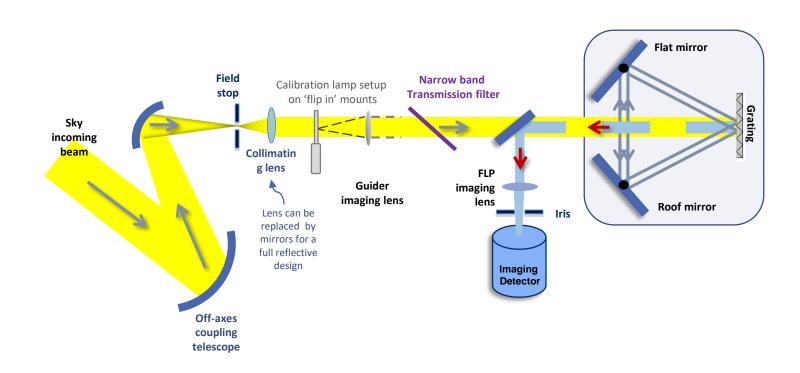


SHS (3 cm)

Volume: 13.5 x 13 x 6 cm

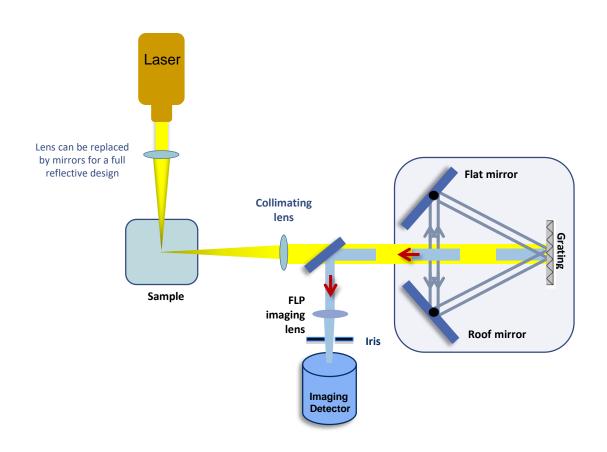


Astronomical Optical layout





Optical layout

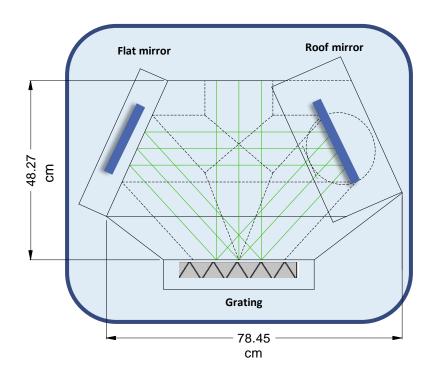


Optical elements and optics are not to scale. SHS has been enlarged for more visibility.



SHS is compact

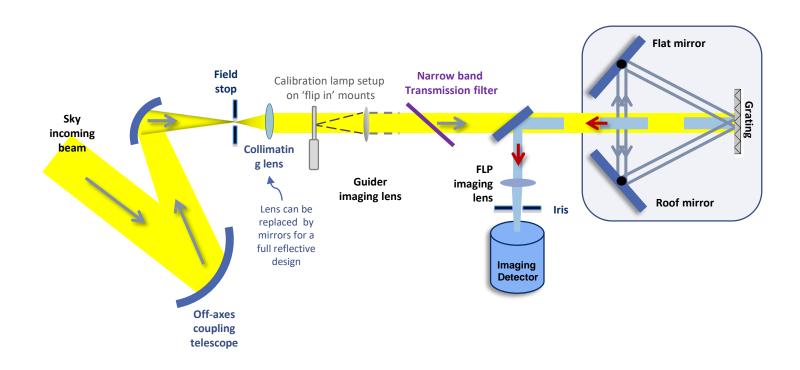
By developing the core of the reflective SHS into a monolithic assembly we provide a way to fabricate robust SHS interferometers in a faster, more flexible, and much more cost effective way by avoiding individual optical mounts and holders for each element in the interferometer.





An example of monolithic optical designs: SHIMMER instrument on STPSat-1.

Medical Optical layout



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Venus night airglow Lunar sodium tail

Earth Science

Wind and Temperature profile OH Measurements

Astrophysics

Direct imaging of exoplanets
Interstellar Medium
H-alpha mapping of Nebula and Galaxies
Solar wind interface



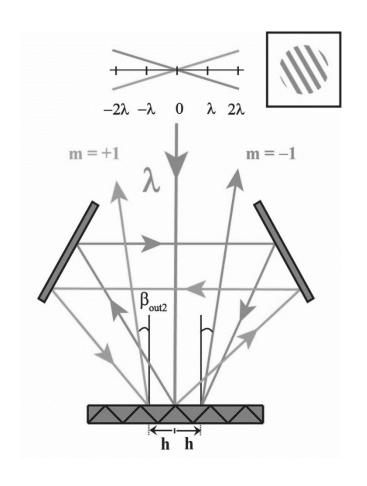
Back Up

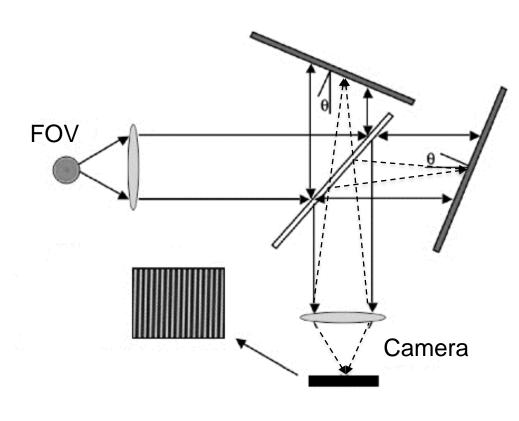


Spatial Heterodyne Spectrometer

Reflective SHS

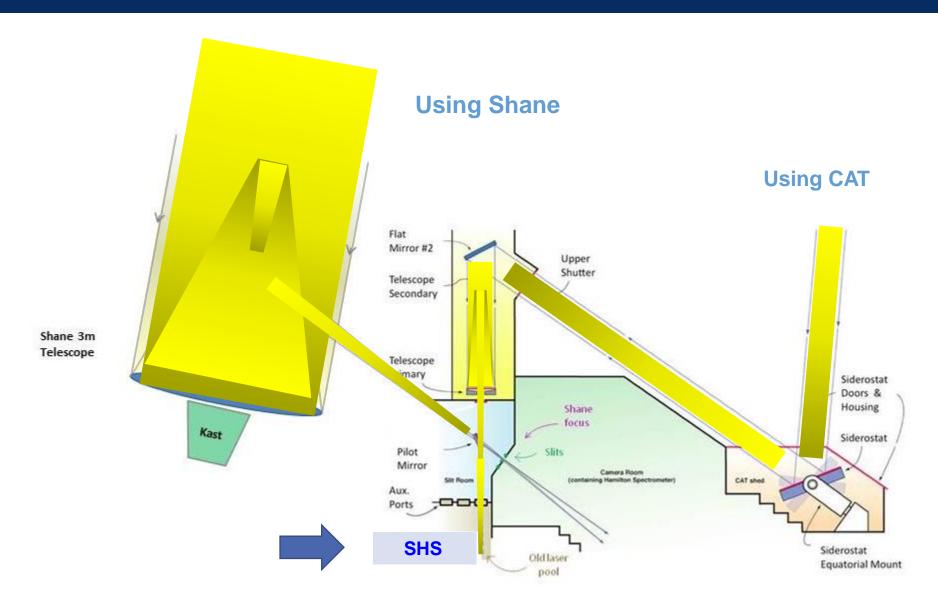
Michelson design SHS





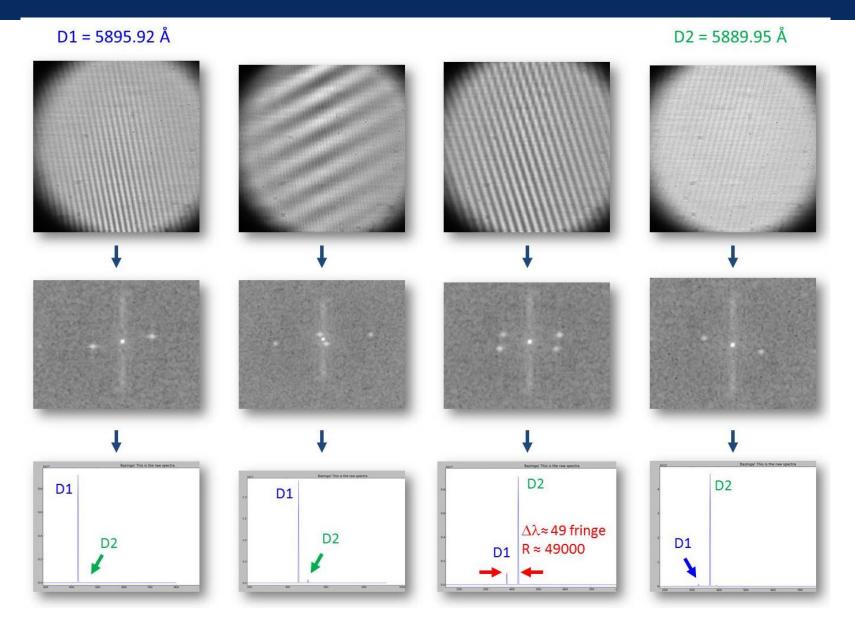


Coupling SHS to the Coudé Auxiliary Telescope (CAT)





Tuning in Na D lines



NASA SHIMMER on STPSat-1

Launched 2007, decommissioned after completing 2.5 years of successful on-orbit operation

Mesospheric hydroxyl (OH)

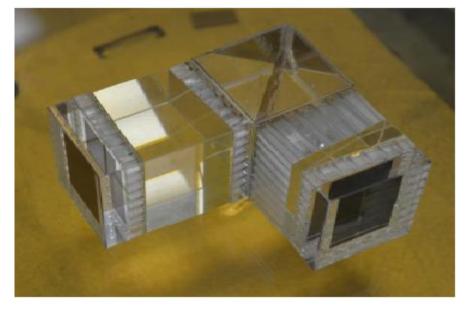


The STPSat-1 small satellite, built for the Department of Defense (DoD) Space Test Program (STP) and operated by the DoD STP for the first year then transitioned to NRL.



\$200 M ICON mission (Tom Immel, UCB; Orbital Sciences)

Earth's thermospheric winds and temperatures at altitudes 90-300 km



Engineering model of the MIGHTI interferometer



MANIC: direct detection of nearby Jupiter-like exoplanets



Boston University, MA with input from Light Machinery Inc.